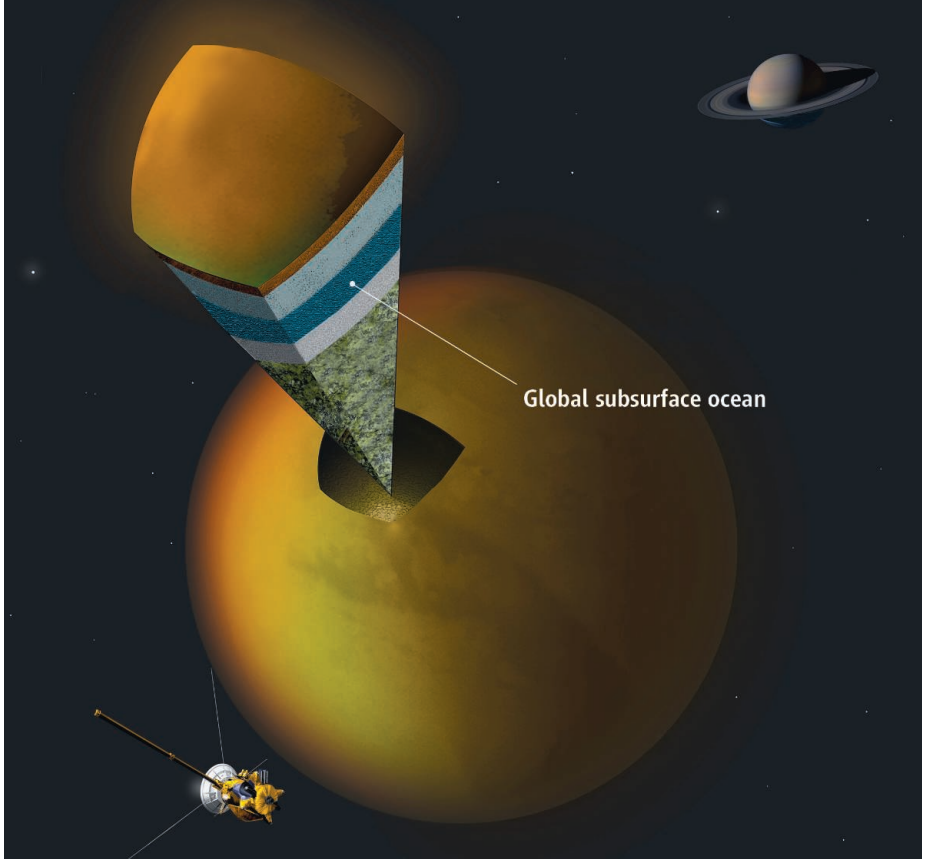

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PLANETARY SCIENCE

Cassini Spies an Ocean Inside Saturn's Icy, Gassy Moon Titan

To understand a planetary body, its origins and its history, it helps to look inside it. Planetary scientists have now done just that in the case of Saturn's big moon Titan, one of the solar system's most enigmatic bodies. Using only the subtly varying pitch of radio transmissions from the Cassini probe as it repeatedly flew by Titan, Cassini scientists have divined an ocean of water 100 kilometers beneath Titan's icy surface.

"It's an enormous technical achievement," says planetary physicist Francis Nimmo of the University of California, Santa Cruz. And it may help explain why the 5150-kilometer-diameter moon "confounds us at every turn," as Nimmo puts it. The only moon with more than a wisp of an atmosphere—Titan's is more dense than Earth's—and the only other solar system object with standing bodies of liquid, Titan may be steadily oozing the methane that sustains its dense cloaking haze and fills its lakes. The newly discovered ocean may have played a role in giving Titan's atmosphere its gas.

On Earth, it is seismologists who probe the interior, using seismic waves. But to peer inside Titan, Cassini scientists instead had to watch how the moon responded to incessant gravitational squeezing by Saturn. As Titan revolves around Saturn every 16 days in its slightly elliptical orbit, the giant planet rhythmically squeezes the moon, something like the way the sun and the moon raise tides in Earth's oceans. The squishier Titan's interior is, the more the moon deforms under the tidal massaging. The more Titan deforms, the more its own gravity field—which depends on the shape of Titan's mass—is distorted.

So the problem of inferring the physical state of Titan's interior became a problem of mapping out Titan's gravity field at different points in its orbit. For that, Cassini team members led by Luciano Iess of Sapienza University of Rome and Robert Jacobson of NASA's Jet Propulsion Laboratory in Pasadena, California, used the Doppler effect. Orbiting Saturn, Cassini beamed radio signals back to Earth during six flybys of Titan. As reported online this week in *Science*, the team measured the varying pitch of those signals precisely enough to gauge Cassini's changing speed with an accuracy of 10 micrometers per second (http://scim.ag/Iessl). That's 36 millimeters per hour for an object that is 1 billion or 2 billion kilometers away.

From Cassini's varying speed, a group led by Iess calculated Titan's varying gravity field, which enabled them to infer its interior state. The group found Titan to be as tidally pliable as if a liquid layer a couple of hundred kilometers thick—no doubt water—encircles the moon beneath 100 kilometers of ice. Another group within the team, led by Jacobson, got the same result using a different and independent method of analysis. "This tells us there must be a liquid layer beneath the surface," Iess says. Nimmo agrees: "I think there's an ocean there." But there seems to be more to Titan's surprisingly pliable interior. Its central region, beneath the ocean, may be solid but unusually soft; or, less likely, the ocean and overlying ice may be extra dense.

The discovery puts Titan in the inner-ocean club with Jupiter's moons Europa, Ganymede, and Callisto. And where there's an ocean, there might be life, right? Not so fast, says planetary physicist David Stevenson of the California Institute of Technology in Pasadena. Titan's ocean "doesn't have anything to do with life," he says. Inside Europa, planetary scientists believe hot springs on a rocky ocean floor may be belching all the nutrients and inorganic building blocks required by life. But other kinds of gravity studies show that Titan has a cold, icy ocean floor, so no hot water can be leaching life-giving chemicals into the ocean. "The interesting question," Stevenson says, "is to what extent is the interior ocean determining, or at least modifying, the geological history of Titan?"

Titan's ocean could conceivably be linked to surface geology as well as the atmosphere's methane, Stevenson says. The sun's ultraviolet radiation is continually cooking the atmosphere's large load of methane into complex organic molecules, the way it did on early Earth before life got started. But this prebiotic chemistry—lifeless but still of great interest to astrobiologists—destroys the atmosphere's methane so fast that it should have disappeared within a few tens of millions of years.

So either Titan got a big shot of methane in the geologically recent past, or methane is being resupplied from the interior. Either way, the ocean may have been involved. Changes in the ocean—perhaps by warming and thinning the overlying shell—may have freed up deep-seated methane. The methane and icy "lava" might then have erupted onto the surface. Some Titan geologists have said they can see the remains of ice volcano eruptions in Cassini radar images, but those claims have not gained much traction. After 8 years orbiting Saturn, Cassini has another 5 years to take quick looks at Titan, inside and out, but researchers would really like a new spacecraft that can linger in orbit about the still-mysterious moon.

–RICHARD A. KERR

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